

Does phosphorus stimulate the effect of elevated [CO₂] on growth and symbiotic nitrogen fixation of grain and pasture legumes?

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Introduction

The atmospheric carbon dioxide (CO₂) concentration has been increasing rapidly since the industrial revolution. The growth response to elevated [CO₂] of legumes is generally greater than non-legumes (Kimball *et al.* 2002), which is due to the higher photosynthetic rate of legumes during plant development (Rogers *et al.* 2006).

The positive effect of [CO₂] on symbiotic N₂ fixation can be limited by a deficiency of other nutrients such as phosphorus (P) (Hungate *et al.* 2004). Many Australian soils are deficient in P, and phosphate fertilizer is commonly applied to improve symbiotic N₂ fixation (Peoples *et al.* 1998). However, the interaction between elevated [CO₂] and soil P status on the symbiotic N₂ fixation of key grain and pasture legumes in Australia is unclear.

Materials and methods

- Glasshouse chambers in Horsham (36°45'S, 142°07'E), Victoria, Australia
- 2 [CO₂] (390 and 700 μmol mol⁻¹) × 2 P levels (0 or 20 kg P ha⁻¹) × 3 legumes (chickpea (*Cicer arietinum* L. cv. Genesis 836), field pea (*Pisum sativum* L. cv. Kaska) and barrel medic (*Medicago truncatula* Gaertn. cv. Mogul)) × 2 soils (Vertosol (P-deficient) and Calcarosol (P-sufficient)) × 4 replications
- The δ¹⁵N values of aboveground parts of legumes and the reference plant (wheat) were used for the calculation of the percentage of plant N derived from the atmosphere (Nd_{fa}) using natural abundance technique.

Results

- Elevated [CO₂] and P application resulted in the greatest above-ground biomass of chickpea, field pea and barrel medic (Fig. 1).
- Elevated [CO₂] increased the grain N yield of chickpea (41%) and field pea (25%) when P was non-limiting, but less profound when P was limiting (Table 1).
- Elevated [CO₂] increased the nodule number (42–44%) and mass (30–58%) of the chickpea, but had no significant effect on either field pea or barrel medic (Fig. 2a–f).
- The percentage of shoot N derived from the atmosphere of the three legumes was unaffected by elevated [CO₂] regardless of soil P supply (Fig. 2g–i).
- Elevated [CO₂] increased the amount of N fixed by chickpea (20–46%), field pea (44–51%) and barrel medic (114–247%) under sufficient P supply (Calcarosol), but had no significant effect when soil P was deficient (Vertosol) (Fig. 2j–l).
- Elevated [CO₂] had no significant effect on the contribution to N balance by either legume in the absence of additional P, but when P was added, elevated [CO₂] increased the soil N removal by these grain legumes (Table 1).

Table 1 Effect of elevated [CO₂] and P application on grain N yield, N fixed and contribution to N balance by chickpea and field pea grown on Vertosol

Treatment	Grain N yield (mg N pot ⁻¹)	N fixed (mg N pot ⁻¹)	Contribution to N balance (mg N pot ⁻¹)
<i>Chickpea</i>			
-P			
Ambient [CO ₂]	52.6	17.0	-35.6
Elevated [CO ₂]	57.7	15.2	-42.5
+P			
Ambient [CO ₂]	110.5	83.1	-27.4
Elevated [CO ₂]	155.4	63.6	-91.9
LSD (p = 0.05)	47.7	38.9	32.4
<i>Field pea</i>			
-P			
Ambient [CO ₂]	65.0	37.1	-27.9
Elevated [CO ₂]	84.8	47.9	-36.9
+P			
Ambient [CO ₂]	234.8	147.6	-87.2
Elevated [CO ₂]	292.7	156.3	-136.4
LSD (p = 0.05)	39.4	72.9	66.9

LSD, least significant difference

Conclusions

- Improved soil P status enhanced the positive effect of elevated [CO₂] on biomass, grain N yield and amount of N fixed by the legumes tested.
- Under predicted future [CO₂] environments, phosphorus application may increase the grain N removal of pulses on a P-deficient soil. The use of pulses alone may not be able to overcome the progressive decline of soil N.

References

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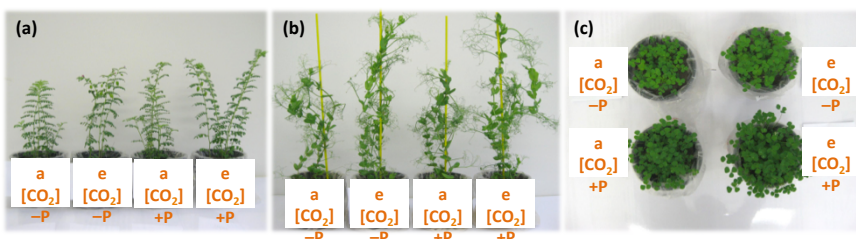


Fig. 1 Chickpea (a), field pea (b) and barrel medic (c) grown under different [CO₂] (a: ambient; e: elevated) and P inputs on Vertosol

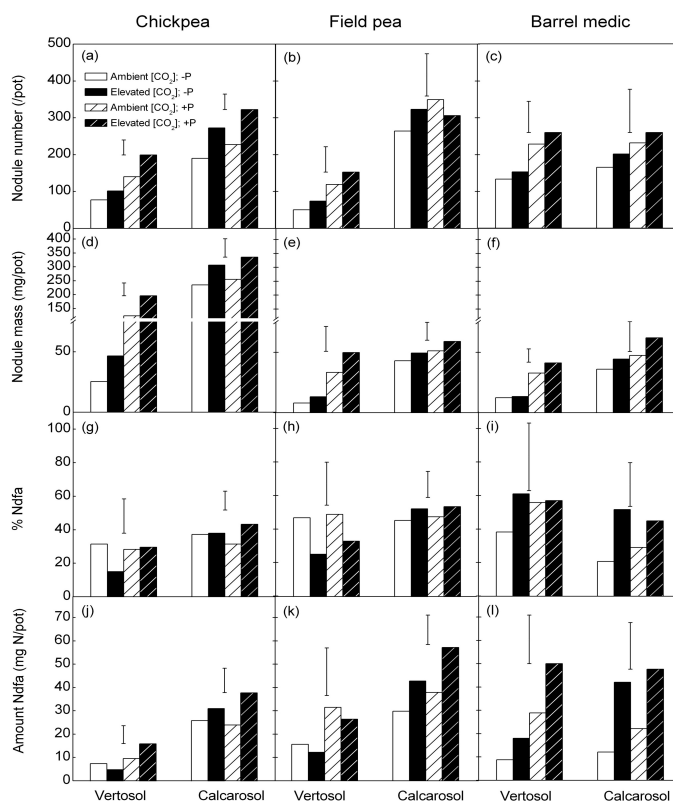


Fig. 2 Effect of elevated [CO₂] and P application on nodule number, nodule mass, and the percentage and amount of N derived from the atmosphere (Nd_{fa}). Error bars indicate LSD (p = 0.05).



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